

LTE & LTE-Advanced Trainings



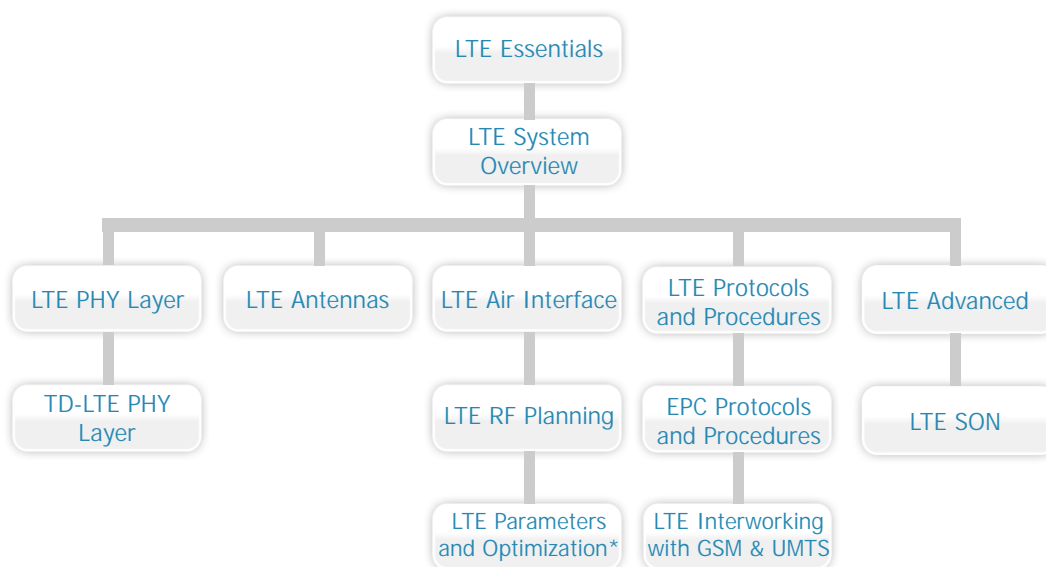
ABOUT US

IS-Wireless is an IPR provider and software developer specializing in OFDM/OFDMA-based radio interfaces. Our portfolio includes implementations of PHY layers for 3GPP LTE and mobile WiMAX. This is complemented by a set of design services targeted mainly at 4G operators and manufacturers. As experts working with OFDM/OFDMA since 1998, we truly believe in the success of these techniques and are fully committed to 3GPP LTE, aiming at solutions for LTE Advanced.

As a part of our business routine we deliver technical courses in the area of 3GPP LTE, WiMAX, OFDM, OFDMA, MIMO, radio network planning and radio interface design. By being active in system design and network planning for LTE and WiMAX, we are able to provide a rare mixture of great theoretical treatment together with a very practical approach. This truly leads to a solid return on investment for our customers. As an outcome, we continuously receive great course evaluations. Last, but not least, we are providing unrivalled post-course support.

LTE TRAININGS

We are proud to offer a complete and comprehensive coverage of radio-related topics describing LTE system.



* under development

Course feedback

Here is what course participants say about our courses:

„Instructor was very knowledgeable – no such thing as a hard question!”

„His experience in the field was a welcome bonus.”

„The LTE instructor was very good, clear and always had an answer for all the doubts and questions.”

„Very good presentations and good interaction with the audience. Presenter VERY skilled in the subject and could explain discuss about all subjects/questions arising. Highly recommendable!”

„Extremely good instructor. Very competent and professional.”

„Excellent instructor! Very clear and always with answers when a doubt was raised.”

„As a new designer I got a really good insight to the theoretical stuff, knowing what I'm actually doing.”

Our courses are delivered globally as instructor-led trainings, either onsite or online.

TARGET GROUP

Our courses are targeted at a vast group of LTE specialists working for telecom vendors, mobile operators, system integrators, consultancies, regulators and research institutions. Depending on the course, prospective participants may be interested in the overall description of the Evolved-UTRAN (E-UTRAN) or Evolved Packet Core (EPC), in the details about E-UTRA interface and its component techniques, in protocols and procedures of the E-UTRAN and EPC network, or finally in the process of planning and optimization of the LTE network. Hence, our courses are suitable for all implementation engineers, system architects, network planners, system testers, tool developers, product managers, technical managers working with LTE or with competing systems such as WiMAX.

RECOMMENDED BACKGROUND

Most of our courses require general knowledge about wireless.

WHY OUR COURSES

There are several reasons to choose our courses. Here are the most important ones:

- all our trainers are also experienced engineers — we talk about the systems that we build ourselves
- the courses are very interactive and practical, enriched by a number of hands-on exercises
- we broadly utilize tools supporting the process of analysis, planning and evaluation of the LTE radio interface and network, while at the same time keeping the course independent from the choice of any particular tool (we are aware that our customers utilize various tools)
- the tools include link-level simulator, system-level simulator and RNP tool (set of tools depends on the course)
- we provide unrivalled post-course support

CUSTOMIZATION

Should you need a customized design, modifications to the offered course or the development of some new parts, do not hesitate to let us know! We would be delighted to adapt our content to your particular needs.



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COURSE OUTLINE

Introduction to LTE

- 2G to 4G radio and core network evolutions (GSM, UMTS, HSPA, LTE and LTE Advanced)
- 3GPP requirements imposed on LTE (throughputs, network capacity, delays)
- Spectrum bands, bandwidths, system parameters and mobile terminal capabilities
- IMT-Advanced requirements for 4G system

LTE System Overview

- LTE network elements: terminals (mobile phone, laptop, PC), access network, core network and IMS
- IP in the network: All IP and always-on concepts
- QoS concept and parameters
- Security in the LTE network (IPsec and LTE security)
- Common IP intersystem part: IMS and its relation to IP-CANs
- Radio access network technologies (OFDMA, MIMO, spectrum flexibility)

LTE Practical Aspects

- LTE performance requirements
- Practically achievable LTE performance (range, coverage, throughputs, number of users)
- Current status of LTE trials and commercial deployments
- Current status of spectrum auctions
- Possible LTE deployment scenarios
- Available handsets and possible evolution

LTE Services

- Potential 4G services
- Flexibly policy and charging options for operators
- SMS and 2G/3G voice in LTE (problems and solutions)
- Packet services: MBMS (mobile TV), internet access, VoD, online gaming, location services
- LTE as competition for fixed networks

LTE Network versus Other Networks

- Network migration possibilities from 2G/3G to LTE
- LTE interworking with UMTS/GSM and WiMAX/WiFi
- LTE international roaming
- LTE compared to WiMAX
- Evolution of LTE towards 4G system (LTE advanced – features, differences, possibilities)

Note: the course content is subject to minor changes and adaptations to the customer needs.

COURSE OUTLINE

Introduction to Evolved Packet System (EPS)

- Evolution steps of the 3GPP systems, the goals for LTE
- LTE bandwidths, bit rates and UE categories
- Summary of radio access techniques

EPS Network Architecture and Interfaces

- E-UTRA and Evolved Packet Core network architecture
- Nodes: UE, eNB, SGW, MME, PGW, PCRF
- Interfaces: Uu, X2, S1, S11, S5, Gx, S6a, SGi, Rx
- IP connectivity, user plane and control plane
- Access Stratum signaling and Non-Access Stratum signaling

OFDMA, SC-FDMA and MIMO

- Fundamentals of multipath propagation (selectivity in time, frequency and space)
- Serial vs. parallel transmission, multicarrier transmission
- OFDM subcarriers and subcarrier separation, cyclic prefix, IFFT/FFT processing
- OFDM transceiver processing
- Multiuser diversity and OFDMA
- SC-FDMA as a subclass of OFDMA, comparison between SC-FDMA and OFDMA
- Multiple access with OFDMA and SC-FDMA
- Multiple antenna concept
- Open and closed loop spatial multiplexing
- Multi-user MIMO

E-UTRA and E-UTRAN

- E-UTRAN protocol stack and channel architecture
- Downlink FDD frame structure and its elements (sub-frames, slots, resource elements, physical resource blocks, PHY channels and signals)
- Adaptive Modulation and Coding, QPSK, 16-QAM, 64-QAM
- Use of MIMO in 3GPP-LTE Release 8
- Uplink FDD frame structure and its elements (sub-frames, slots, resource elements, physical resource blocks, PHY channels and signals)
- E-UTRAN L3 and L2 protocols: RRC, PDCP, RLC, MAC

Quality of Service in LTE

- Bearer architecture including EPS bearer and end-to-end service
- Guaranteed and Non-Guaranteed Bit Rate Bearer
- QoS Classes and QoS Class Identifier
- Allocation and Retention Priority
- Bit Rate limitations
- Bearer setup, service data flows and traffic flow templates

Evolved Packet Core

- Overview of EPS protocols: PDCP, RRC, GTP, X2AP, S1-AP, S1-MME, GTP, Diameter
- NAS protocols (EMM and ESM)
- UE states (LTE-idle, LTE-active, LTE-detached)
- Subscriber identities and their relations (IMEI, IMSI, GUTI, S-TMSI, RNTIs)
- Security and keys' derivation
- IMS network and nodes (CSCF, AAA, DNS, AS, HSS)
- Call establishment via IMS
- Voice in LTE (CS Fallback, Voice Call Continuity, VoLGA)

LTE Cross-system Procedures

- Network Attach and Detach
- Call setup (Dedicated bearer establishment)
- Tracking Area Update
- Paging
- Handover over X2
- Handover over S1

LTE Features Roadmap (Rel. 8-10)

- Overview of features in the 3GPP E-UTRAN Release 8
- Enhancements expected in 3GPP E-UTRAN release 9 including MBMS
- Features in 3GPP E-UTRAN Release 10 i.e., LTE Advanced: spectrum aggregation, relay concept, MIMO improvements

LTE Interworking Considerations

- Roaming
- Inter-working with 3GPP and non-3GPP networks

Note: the course content is subject to minor changes and adaptations to the customer needs.

COURSE OUTLINE

Introduction to Evolved Packet System (EPS)

- Evolution steps of the 3GPP systems, the goals for LTE
- E-UTRA and Evolved Packet Core network architecture
- Nodes: UE, eNB, SGW, MME and interfaces: Uu, X2, S1, S11
- Summary of the radio access techniques
- E-UTRAN protocol stack
- System parameters (bandwidths, bands, throughputs)

Signal Processing for OFDMA, SC-FDMA and MIMO

- Fundamentals of multipath propagation (selectivity in time, frequency and space)
- OFDM transmission, orthogonality, subcarriers, separation between subcarriers
- Time-domain and frequency-domain representation of the OFDM signal
- Guard interval and Cyclic Prefix (CP) role
- Equalization for OFDM
- IDFT/DFT, IFFT/FFT
- Multiuser diversity and OFDMA
- SC-FDMA as a subclass of OFDMA, comparison between SC-FDMA and OFDMA
- Multiple antenna concept and related signal processing
- Open and closed loop spatial multiplexing
- Single-user and Multi-user MIMO

Signal Processing for the Evolved Node B

- Architecture of the eNB transmitter and receiver including processing blocks and signals
- E-UTRA radio frame for FDD
- Downlink channel architecture
- eNB-originated signals and PHY channels: RS, P-SS, S-SS, PBCH, PCFICH, PHICH, PDCCH, PDSCH
- 3GPP Rel. 8 MIMO processing with layer mapping, pre-coding and feedback

Signal Processing for the User Equipment

- LTE UE categories
- Architecture of the UE transmitter and receiver including processing blocks and signals
- Uplink channel architecture

- UE-originated signals and PHY channels: DRS, SRS, PUCCH, PUSCH, PRACH

Evaluation of the eNB and UE Transceiver Operation Under Various Conditions

- Impact of uncorrected multipath channels
- Peak-to-average-power-ratio and its influence on the transmitted signal
- Pulse shaping and filtering in the time domain and its influence on the transmitted signal
- Synchronization mismatches in the time and frequency domain and their influence on the received signal
- Influence of various types of interferers (single-dominant, non-single-dominant) on the received signal

Radio Interface Procedures

- Various traffic allocations for the FDD downlink and uplink E-UTRA radio frame
- Various traffic allocations for the TDD downlink and uplink E-UTRA radio frame
- Synchronization and random access procedures
- Scheduling for FDD
- ARQ operation and feedback consideration

Processing Improvements in E-UTRA 3GPP Rel. 9 and Rel. 10

- Usage of 8 antennas in the downlink for spatial multiplexing
- Transmit diversity in the uplink
- Spatial multiplexing in the uplink
- Coordinated MIMO
- Bandwidth aggregation

Note: the course content is subject to minor changes and adaptations to the customer needs.

COURSE OUTLINE

Introduction to E-UTRA TDD

- Evolution steps of the 3GPP systems, the goals for LTE
- E-UTRA and Evolved Packet Core network architecture
- Nodes: UE, eNB, SGW, MME and interfaces: Uu, X2, S1, S11
- Summary of the radio access techniques
- E-UTRAN protocol stack
- Channel bandwidths and RF limitations for FDD and TDD

Signal Processing for OFDMA, SC-FDMA and MIMO

- Fundamentals of multipath propagation (selectivity in time, frequency and space)
- OFDM transmission, orthogonality, subcarriers, separation between subcarriers
- Time-domain and frequency-domain representation of the OFDM signal
- Guard interval and Cyclic Prefix (CP) role
- Equalization for OFDM
- IDFT/DFT, IFFT/FFT
- Multiuser diversity and OFDMA
- SC-FDMA as a subclass of OFDMA, comparison between SC-FDMA and OFDMA
- Multiple antenna concept and related signal processing
- Open and closed loop spatial multiplexing
- Single-user and Multi-user MIMO

Signal Processing for the TDD Evolved Node B

- Architecture of the eNB transmitter and receiver including processing blocks and signals
- E-UTRA radio frame for FDD
- TDD Radio frame and special sub-frame configuration
- Coexistence with TD-SCDMA
- Downlink channel architecture
- eNB-originated signals and TDD PHY channels: RS, P-SS, S-SS, PBCH, PCFICH, PHICH, PDCCH, PDSCH
- TDD synchronization signal mapping
- 3GPP Rel. 8 MIMO processing with layer mapping, pre-coding and feedback

Signal Processing for the TDD User Equipment

- LTE UE categories
- Architecture of the UE transmitter and receiver including processing blocks and signals
- Uplink channel architecture
- UE-originated signals and TDD PHY channels: DRS, SRS, PUCCH, PUSCH, PRACH
- Evaluation of the eNB and UE Transceiver

Operation Under Various Conditions

- Impact of uncorrected multipath channels
- Peak-to-average-power-ratio and its influence on the transmitted signal
- Pulse shaping and filtering in the time domain and its influence on the transmitted signal
- Synchronization mismatches in the time and frequency domain and their influence on the received signal
- Influence of various types of interferers (single-dominant, non-single-dominant) on the received signal
- TDD DL and UL sub-frame mismatches

Radio Interface Procedures

- Various traffic allocations for the TDD downlink and uplink
- E-UTRA radio frame
- Synchronization and random access procedures
- Scheduling for FDD and TDD
- Hybrid ARQ operation for FDD and TDD; feedback consideration
- TDD HARQ bundling and multiplexing

Processing Improvements in E-UTRA 3GPP Rel. 9 and Rel. 10

- Usage of 8 antennas in the downlink for spatial multiplexing
- Transmit diversity in the uplink
- Spatial multiplexing in the uplink
- Coordinated MIMO
- Bandwidth aggregation

Note: the course content is subject to minor changes and adaptations to the customer needs.

COURSE OUTLINE

Introduction to E-UTRA

- Evolution steps of the 3GPP systems, the goals for LTE
- E-UTRA and Evolved Packet Core network architecture
- Nodes: UE, eNB, SGW, MME
- Interfaces: Uu, X2, S1, S11
- LTE bandwidths, bit rates and UE categories
- Summary of radio access techniques
- E-UTRAN protocol stack
- Alternative systems: Mobile WiMAX

Overview of OFDMA and SC-FDMA

- Fundamentals of multipath propagation (selectivity in time, frequency and space)
- Basics of OFDM transmission, subcarriers, cyclic prefix, IFFT/FFT processing
- OFDMA and SC-FDMA as extension of OFDM
- Multiple access with OFDMA and SC-FDMA
- Advantages and disadvantages of OFDM, OFDMA and SCFDMA

LTE Downlink PHY Layer Processing

- Downlink channel architecture (radio bearers, logical, transport and physical channels)
- Downlink FDD frame structure and its elements (sub-frames, slots, resource elements, physical resource blocks, PHY channels and signals)
- PHY channels and signals including: PBCH, PCFICH, PHICH, PDCCH, PDSCH, Primary and Secondary Synchronization Signals, Reference Signals)
- Various antenna pilot patterns and Reference Signals for MIMO
- MIMO processing in 3GPP-LTE Release 8
- Placement of control channels (PCFICH, PHICH, PDCCH) in the control region
- Downlink processing chain including channel coding and rate matching, modulation, layer mapping, pre-coding, resource element mapping and OFDMA signal generation
- Downlink control information, PDCCH formats, mapping of DCI into PDCCH
- PDCCH blind decoding
- PHICH assignment

LTE Uplink PHY Layer Processing

- Uplink channel architecture (radio bearers, logical, transport and physical channels)
- Uplink FDD frame structure and its elements (sub-frames, slots, resource elements, physical resource blocks, PHY channels and signal)
- PHY channels and signals including PUCCH, PUSCH, SRS, DRS, PRACH
- PUCCH formats
- Creation of SRS
- Random Access Preamble formats
- Location of PRACH in the uplink frame

- Uplink processing chain including channel coding and rate matching, modulation, resource element mapping and SCFDMA signal generation
- PUSCH hopping procedure and UE SRS procedure

LTE MAC Layer

- MAC architecture and functions
- Priority handling and multiplexing
- Hybrid ARQ (HARQ) operation (Chase combining and incremental redundancy)
- HARQ processes and processing HARQ ACKs and NACKs by PHY layer
- Discontinuous Reception (DRX) and Semi-Persistent Scheduling (SPS)
- Adaptive Modulation and Coding
- Timing Relationship and Timing Advance
- Scheduling

LTE RRC, PDCP and RLC Layers

- RRC procedures including system info broadcasting, paging, RRC connection establishment, security establishment, NAS message transport and RRC connection reconfiguration
- Types of radio bearers
- RRC connection establishment: from RRC Idle to RRC Connected
- PDCP architecture and functions: robust header compression, ciphering and integrity protection
- RLC architecture and functions including segmentation / concatenation, retransmissions
- RLC modes: Transparent, Unacknowledged, Acknowledged
- Example LTE data flow and transport block sizes

Radio Interface Procedures

- Downlink resource assignment, resource allocation types, resource block grouping
- Modulation and transport block size determination
- Synchronization and system info acquisition
- RRC measurement reporting
- UE mobility states
- Measurements: RSRP, RSSI, RSRQ
- Overview of E-UTRA reporting events
- Cell selection / reselection
- Random Access procedure
- MIMO feedback reporting (PMI and RI)
- CQI, PHR and BSR reporting
- Uplink power control, open loop and closed loop, types of transmit power commands
- Downlink power control - operation and parameters
- X2 interference management and load balancing procedures

LTE Air Interface Demo and Experiments (tool-based)

- OFDMA and SC-FDMA waveforms
- Chosen eNB and UE signals and PHY channels shown in the time and frequency domain
- Complete downlink and uplink radio frame shown as time-frequency grid

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COURSE OUTLINE

Introduction to EPS

- Evolution steps of the 3GPP systems, the goals for LTE
- LTE bandwidths, bit rates and UE categories

EPS Network Architecture

- E-UTRA and Evolved Packet Core network architecture
- Nodes: UE, eNB, SGW, MME, PGW, PCRF
- Interfaces: Uu, X2, S1, S11, S5, Gx, S6a, SGi, Rx
- Overview of EPS protocols: PDCP, RRC, GTP, X2AP, S1-AP, S1-MME, GTP, Diameter
- IP connectivity, user plane and control plane
- Access Stratum signaling and Non-Access Stratum signaling
- E-UTRAN protocol stack and channel architecture
- E-UTRAN L3 and L2 protocols: RRC, PDCP, RLC, MAC, PHY

Non-Access Stratum (NAS) Protocols

- NAS protocols (EMM and ESM)
- UE states and state transitions (LTE-idle, LTE-active, LTE-detached)
- Subscriber identities and their relations (IMEI, IMSI, GUTI, STMSI, RNTIs)
- Security and keys' derivation
- Integrity and Encryption - SNOW 3G, AES
- EPS Authentication and Key Agreement; Key Hierarchy
- Key distribution and mobility
- NAS message structure

Radio Resource Control (RRC) Protocol

- RRC procedures including system info broadcasting, paging, RRC connection establishment, security establishment, NAS message transport and RRC connection reconfiguration
- Types of radio bearers
- RRC States & State Transitions

Packet Data Convergence Protocol (PDCP)

- PDCP architecture
- PDCP Functions (robust header compression, ARQ at handover, status reporting ciphering and integrity protection)
- PDCP message structure for Data and Control

Radio Link Control (RLC) Protocol

- RLC architecture (Transparent Mode, Unacknowledged Mode, Acknowledged Mode)
- Functions (segmentation / concatenation, ARQ procedures)
- RLC PDU formats (RLC user plane and control PDUs)

MAC Protocol

- MAC Architecture
- MAC PDU: user plane and control plane parts
- Scheduling procedures for downlink and uplink resource assignments
- Scheduling Requests, Buffer Status Reports and Power Headroom Reports
- Hybrid-ARQ processes and HARQ operation
- Mapping of Logical Channels to Transport Channels

- MAC level identities mapping

LTE PHY Layer

- Logical, Transport and Physical channels and their relation to the radio interface protocol stack (i.e. Channel architecture)
- Adaptive Modulation and Coding, QPSK, 16-QAM, 64-QAM
- Principles of OFDM/OFDMA/SCFDMA
- Principles of MIMO
- Downlink and uplink frame structure and its elements (PRB, RE, CCE)
- L1 control information, formats and signaling
- Resource mapping to radio frame
- PHY layer related scheduling principles (including "maximum SNIR", "round robin" and "proportional fair" schedulers)

S1 Interface Procedures

- S1 CP and UP protocol stacks
- S1 Application Protocol (S1-AP)
- S1-AP identifiers
- S1-AP procedures: S1 association and SON related procedures, UE related procedures
- GTP-U protocol (including tunneling concept and TEID)

X2 Interface Procedures

- X2 CP and UP protocol stacks
- X2 Application Protocol (X2-AP)
- X2-AP identifiers
- X2-AP procedures: X2 association procedures, UE related procedures, SON related procedures

S11, S5/S8, S10 Interface Procedures

- CP and UP protocol stacks for each interface
- GTP-C (eGTP) protocol
- GTP-C message header and tunneling concept
- Functions and procedures related to each interface (UE context exchange, call establishment, bearer management, etc.)

IMS and End-to-End Signaling

- IMS architecture (S-CSCF, P-CSCF, I-CSCF, HSS, AS, etc.)
- IMS security and PCC considerations
- SIP Basics - registration, session establishment
- IMS end-to-end protocol stack
- IMS end-to-end call establishment
- Voice in LTE (CS Fallback, Voice Call Continuity, VoLGA)

Interworking with 3GPP and non-3GPP networks

- Roaming
- Inter-working with 3GPP and non-3GPP networks
- Inter-RAT handover: example of handover between LTE and UMTS

Note: the course content is subject to minor changes and adaptations to the customer needs.

COURSE OUTLINE

Introduction to EPS

- Evolution steps of the 3GPP systems, the goals for LTE/SAE
- Current status of the EPS standardization process

EPS Network Architecture

- IP in the Core Network
- Nodes and their roles: UE, eNB, SGW, MME, PGW, PCRF, HSS
- Interfaces: Uu, X2, S1, S11, S5, Gx, S6a, SGi, Rx
- Overview of EPC protocols: GTP, X2AP, S1-AP, S1-MME, GTP, Diameter
- IP connectivity, user plane and control plane
- Access Stratum signaling and Non-Access Stratum signaling

Evolved Packet Core Protocols

- NAS protocols (EMM and ESM)
- EMM, ECM and RRC states and state transitions
- Subscriber identities and their relations (IMEI, IMSI, GUTI, S-TMSI, RNTIs)
- Control plane EPC protocols: S1-AP and GTP-C over SCTP
- User plane EPC protocols: GTP-U over UDP
- S1 Application Protocol (S1AP) procedures
- Main GTP procedures in EPS
- The GTP version 2 protocol (eGTP)
- General message headers

Evolved Packet Core Procedures

- Mobility management (Tracking Area Update)
- MMEs in the Pool (pool area, MME selection and addressing, load balancing, overload control)
- Network Attach and Detach
- Session establishment and control (call establishment procedure)
- QoS related procedures (default and dedicated bearer, QoS Parameters, PDN Connectivity Request and EPS Bearer Establishment)
- User data transfer (GTP tunneling concept, tunnel establishment)
- Service request procedure (UE- and network-triggered)

IMS Protocols

- IMS architecture and nodes (S-CSCF, P-CSCF, I-CSCF, AS, HSS, MRFC, MRFP, etc)
- Control plane protocols: SIP and SDP
- User plane protocols: RTP and RTCP
- End-to-end IMS protocol stack
- UICC and ISIM and USIM (Subscriber modules)
- Public and private user identities
- IP in the EPS/IMS (IETF Dependence, dynamic UE address allocation)
- User profiles (IMS service profile) and filter criteria

IMS Procedures and Services

- Service Control and the IMS
- Charging Requirements and Functionality (AAA charging example)
- IMS discovery
- SIP signaling procedures – registration, invitation, security
- End-to-end call establishment via IMS
- Services: SMS, Voice (CS Fallback, Voice Call Continuity, VoLGA)

Security in EPS and IMS

- Security architecture (key hierarchy) and keys' derivation
- Integrity and encryption - SNOW 3G, AES
- Key distribution and mobility aspects
- EPS authentication (AAA procedures)
- User-to-Network security mechanisms
- Network domain security mechanisms (IPsec in EPS and IMS with ESP and IKE)
- The IMS security architecture
- Diameter protocol, commands, applications and Attribute Value Pairs
- Diameter nodes and 3GPP extensions
- MME - HSS interface (S6a) and signaling with the use of Diameter
- S-CSCF - HSS interface (Cx) and signaling with the use of Diameter

Policy and Charging Control in EPS and IMS

- IP Connectivity Access Networks (IP-CANs) relation to PCC
- IP-CAN bearer establishment procedure
- IMS based charging principles (PCC rules and high level PCC operation)
- PCC nodes and functions (PCRF, PCEF, AF and SPR)
- QoS handling and authorization (filtering of user data and gating)
- QoS parameter mapping and management functions
- User plane handling in the PCEF
- Charging architecture (including CDR)
- Online, offline and roaming charging

EPC Interworking with Other Networks

- Inter-working with 3GPP and non-3GPP networks
- S3 interface and protocol stack (MME and SGSN)
- S4 interface and protocol stack (SGW and SGSN)
- Example interworking procedures (handover between LTE and UMTS, ISR concept and operation)
- Roaming scenarios (local breakout and home routed access)
- Interworking security considerations (example of untrusted non-3GPP access)
- Access Network Discovery and Selection Function (ANDSF) functionality and operation

Note: the course content is subject to minor changes and adaptations to the customer needs.

COURSE OUTLINE

Introduction to EPS and Interoperability

- Evolution of 3GPP systems (GSM, UMTS, LTE)
- Evolution of 3GPP2 systems (IS95, cdma2000, eHRPD)
- Evolution of IEEE systems (WiFi, Fixed WiMAX, Mobile WiMAX)
- EPS basic interworking architecture for 3GPP, non-3GPP trusted and untrusted access
- Main LTE interoperability scenarios (network selection, idle mode mobility, PS and CS handovers)

3GPP Interworking System Architecture

- E-UTRAN and EPC nodes and internal interfaces
- GSM and UMTS architectures (pre-Rel. 8 and Rel. 8)
- Interfaces between GSM / UMTS and EPS (S3, S4, S12, S6d, etc.)
- GSM / UMTS / EPS protocol stacks (including interworking protocols – GTP-C / GTP-U / SCTP)
- GSM / UMTS / EPS bearers concepts and configuration
- UE identities within GSM / UMTS and EPS
- TIN concept – mapping between GUTI/S-TMSI and RAI/P-TMSI
- Security interoperability aspects (ciphering / integrity protection keys conversion and authentication vectors transfer)

Radio Interface Related Interoperability Issues

- System information for interworking control (cell selection / reselection parameters for E-UTRAN, GERAN, UTRAN, cdma2000, etc.)
- UE measurements for cell selection / reselection (cell search procedures for GERAN, UTRAN, E-UTRAN)
- Cell selection / reselection algorithm for Inter-RAT (inter-RAT priority based cell reselection)
- UE measurements and reporting for intra LTE and inter-RAT handover (periodic and event-triggered)
- Measurement gaps configuration for inter-RAT measurements
- Handover related RRC signaling (RRC connection reconfiguration, Mobility from E-UTRA command)
- RRC States (E-UTRAN and Inter-RAT RRC state machines and state changes)

EPS Idle Mode Interworking

- PLMN selection
- UE location – Location Areas (GERAN), Routing Areas (UTRAN), Tracking Areas (E-UTRAN)
- Idle-mode signaling reduction (ISR) and combined attach

- Combined Routing and Tracking Area Updates
- Context transfer between MME and SGSN (including UE capabilities for GERAN, UTRAN and E-UTRAN)
- Paging procedures for PS and CS domain
- Inter-RAT signaling flows including attach, paging, location registration (GPRS / EPS attach, inter-RAT location registration)

EPS Connected Mode Interworking for Packet Switched (PS) Domain

- PS mobility between E-UTRAN and UTRAN / GERAN (PS handover and NACC)
- QoS control for interoperability within 3GPP systems
- QoS parameters translation between EPS and UMTS “language” (bearer mapping – PDP to EPS bearer)
- Policy and charging control for PS interoperability
- Signaling flows of E-UTRAN inter-RAT handover to / from UTRAN / GERAN and comparison to intra-LTE handover
- LTE roaming issues (home routed and local breakout)

EPS Connected Mode Interworking for Circuit Switched (CS) Domain

- Plain CS voice, SMS services and challenges resulting from PS/CS domain transfer
- IMS role in the interoperability between PS and CS (including IMS architecture and SIP signaling)
- CS voice solutions in EPS and IMS networks (CS fallback, SR-VCC)
- SMS solutions in EPS and IMS (CS fallback, SMS-over-IP)
- GSMA solutions for CS services: voice and SMS over LTE (VoLTE)
- Signaling flows for CS voice mobility between EPS and GSM / UMTS (e.g. CSFB call setup)

LTE Interworking with non-3GPP Networks

- Interfaces for interoperability between E-UTRAN and eHRPD, WiMAX and WiFi
- Mobility between E-UTRAN and eHRPD (a.k.a. 1xEV-DO)
- Mobility between E-UTRAN and Mobile WiMAX
- Interworking with untrusted WiFi access
- Security issues for interworking with non-3GPP trusted and untrusted networks
- The use of Access Network Discovery and Selection Function (ANDSF)

Note: the course content is subject to minor changes and adaptations to the customer needs.

COURSE OUTLINE

Radio Propagation Overview and Antenna

- Fundamentals
- Propagation in dispersive multipath channels
- Basic antenna characteristics (time, frequency and angular spread)
- Vertical, horizontal and circular polarization of electromagnetic wave
- Basic antenna structures (isotropic and dipole), their characteristics and parameters
- Sector antenna pattern, influence of down-tilting
- Line-of-sight and non-line-of-sight propagation

Spatial Diversity Methods

- Three domains for providing diversity (time, frequency and space)
- Diversity combining schemes: MRC for receive diversity, Alamouti for transmit diversity and selection combining for both
- Combination of spatial diversity (RAKE receiver and cyclic delay diversity)
- Use of space time coding (STBC, STTC)

Beamforming

- Fundamentals of creating adaptive antenna patterns
- Transmit and receive beamforming (DoD and DoA)
- Physical vs. mathematical beamforming
- Switched multibeam vs. adaptive antenna array
- Optimal usage of beamforming (desired signal enforcement, interference suppression or cancellation)
- Combination of beamforming with spatial diversity or spatial multiplexing
- Practical examples of range increase

Spatial Multiplexing

- Basic idea of creating independent spatial channels
- General mathematical model for spatially multiplexed channels
- Encoder and decoder for Horizontal Layered Space (H-BLAST)
- Encoder and decoder for Vertical Layered Space (V-BLAST)
- Encoder and decoder for Diagonal Layered Space (D-BLAST)
- Spatial multiplexing with feedback (closed loop)
- Water-filling concept in closed loop MIMO
- Zero-forcing receiver and singular value decomposition (SVD)

MIMO in Multiple-user Scenario

- Extension of spatial multiplexing concept to multiple-user scenarios

- Classification of multiple-user scenarios for MIMO usage
- 3-dimensional scheduling in LTE system
- Coordinated MIMO transmission from more than one base station

Combination of MIMO with OFDMA and SC-FDMA

- OFDMA and SC-FDMA as the key transmission techniques in the LTE specs
- MIMO-related synchronization and channel estimation aspects
- Combination of STBC and OFDMA
- Combination of SM/BF and OFDMA
- Possible allocations of transmit diversity and spatial multiplexing
- Receive beamforming with SC-FDMA

E-UTRA Release 8 MIMO Processing

- Downlink and uplink scenarios for Rel. 8 MIMO
- Pilot patterns for 1, 2 and 4 antenna ports at the eNB
- Signal processing chain for MIMO including eNB transmitter and UE receiver
- MIMO mapping including transport blocks, codewords and layers
- MIMO operation for SFBC, spatial multiplexing and beamforming
- MIMO modes and feedback (PMI, RI)

E-UTRA Release 10 and Beyond MIMO Enhancements

- 8x8 spatial multiplexing in downlink and new reference signals
- 4x4 spatial multiplexing in uplink
- SU-MIMO for PUSCH and transmit diversity for PUCCH
- Coordinated multipoint transmission in downlink
- Coordinated multipoint reception in uplink

LTE MIMO in Network Deployment

- Antenna system elements and site configurations
- Practical realization of MIMO configurations
- MIMO impact on coverage, capacity, reliability and interference
- Influence on link budgets and capacity budgets
- Typical design trade-offs in application of MIMO

Numerical Experiments (tool-based)

- MIMO processing at eNB transmitter (including SISO, TX Diversity, Spatial Multiplexing)
- MIMO related reference signals
- Channel correlation influence on spatial stream separation

Note: the course content is subject to minor changes and adaptations to the customer needs.

COURSE OUTLINE

Introduction to LTE Advanced

- Evolution path of 3GPP LTE systems (standardization time plan in 3GPP)
- Features of LTE releases
- Requirements and performance targets of LTE Advanced and its relation to requirements of IMT Advanced for 4G systems
- Identified IMT-Advanced spectrum allocations
- Release 8 and 9 air interface features
- Summary of LTE-Advanced enhancements on the radio interface
- LTE Bands, bandwidths, throughputs and UE categories
- Possible services for LTE-Advanced (e.g. positioning, internet of things, MBMS, broadband access, etc.)

EPS Network Architecture Improvements

- Release 8 nodes and interfaces (UE, eNB, MME, SGW, PGW)
- Release 9 scenarios (MBMS, Positioning)
- Release 10 enhancements in EPS (added Relays and enhanced Home eNodeB)

E-UTRA Rel. 9 Features

- Multimedia Broadcast Multicast Service (MBMS)
- MBMS architecture and PHY issues
- Self-organizing and self-optimizing networks (SON)
- SON architecture and functionalities
- LTE Positioning concept, architecture and possible location services

E-UTRA Rel. 10 PHY Enhancements

- Multicarrier transmission (OFDM/OFDMA/SCFDMA)
- Refreshment of the Rel. 8 E-UTRA (including protocol stacks, downlink and uplink radio frames, PHY channels and signals)
- Clustered SCFDMA for uplink in Rel. 10
- Bandwidth extension by carrier aggregation (use of component carriers)
- Processing of Component carriers
- Various scenarios of carrier aggregation
- RF aspects related to carrier aggregation
- Enhanced Downlink MIMO (for up to 8 antennas)
- Additional Downlink MIMO reference symbols for higher order MIMO (CSI-RS, DM-RS)
- Processing chain for DL MIMO (and comparison to Rel. 8 processing chain)
- New UL MIMO schemes (SU-MIMO for PUSCH and TX Diversity for PUCCH)
- Processing chain for UL MIMO (and comparison to Rel. 8 processing chain)

E-UTRA Rel. 10 Protocols and Procedures

- Protocol stack for Carrier Aggregation
- CA procedures (addition and release, activation and deactivation of component carrier)
- Primary and Secondary Component Carriers for Downlink OFDMA and Uplink SCFDMA

- Idle and Connected mode issues (System info acquisition and RRC signaling for CA usage, RRC idle-to-connected state change and HO timing requirements)
- CA challenges (scheduling and Handover aspects)
- MAC issues with relation to CA: user data allocation and signaling aspects (including cross carrier scheduling)
- Additional L1 signaling formats (PUCCH format 3 and DCI format 4)

E-UTRA Rel. 10 Relays

- Relay concept and roles for capacity and coverage enhancements
- Types of relays (Repeaters and Relay Nodes)
- L3-Relay Node (RN) in LTE-Advanced specifications (protocol stacks, architecture and roles of DeNB)
- RN procedures (activation and relaying operation)
- L1 issues (R-PDCCH & MBSFN sub-frame usage for relay link)
- Timing requirements for relay link

E-UTRA Rel. 10 Home eNBs, HetNets and SON

- LTE HeNB architecture possibilities (HeNB, HeNB GW and SeGW)
- Access control and CSG management (types of cells: open, hybrid and closed)
- Heterogeneous Network (HetNet) concept (Macro, Pico, Femto cells and relays)
- Interference scenarios
- LTE inter cell interference coordination (ICIC) in time and frequency

E-UTRA Release 11 and Beyond Features

- Cooperative Multipoint Transmission/Reception
- CoMP downlink and uplink scenarios
- Mobile Type Communications (MTC) concept and possible services
- Mobile Relays concept

LTE Advanced Deployment

- Backward compatibility to LTE Rel. 8 requirements
- Transparency of Relay nodes (and RNs deployment issues)
- Migration from LTE Rel. 8 to LTE Advanced Rel. 10
- HetNet deployment

LTE Advanced Demo and Experiments (tool-based)

- Usage of 8 antennas in the downlink for spatial multiplexing
- Spatial multiplexing in the uplink
- Bandwidth aggregation

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COURSE OUTLINE

LTE RF Design Process

- RF Planning workflow
- Inputs to and targets for the planning process; expected outputs
- Coverage and capacity requirements
- Planning constraints
- Significant differences in planning for GSM and UMTS

EPS Overview and E-UTRAN Consideration (tool-based)

- Evolved Packet System architecture
- E-UTRAN architecture: nodes and interfaces
- eNB and UE architecture
- Radio frame for E-UTRA FDD and TDD
- Reference signals and pilots: RS, P-SS, S-SS, DRS, SRS
- PHY channels in the downlink: PBCH, PDCCH, PCFICH, PHICH, PDSCH
- PHY channels in the uplink: PRACH, PUCCH, PUSCH
- Link-level radio interface simulations

Radio Propagation Principles (tool-based)

- Spectrum considerations and LTE frequency bands
- RF requirements imposed on UE and eNB transceivers
- Large-scale and small-scale propagation effects; path-loss, shadowing and fading
- Propagation models: statistical, empirical and deterministic
- Configuration and tuning of the propagation model

Antenna Considerations and MIMO

- Antenna properties – size, gain, beam-width, polarization, front-to-back ratio
- LTE diversity techniques
- Spatial multiplexing, single-user and multi-user MIMO
- Transmission modes and MIMO feedback signaling
- Impact on LTE link budget and capacity
- Antenna system sharing options

Coverage Planning and Link Budgets (tool-based)

- Link budgets, gains and losses
- Role of adaptive modulation and coding scheme
- Requirements for signal-to-noise-and-interference ratio (SNIR) and receiver sensitivity
- Thermal noise calculations and interference estimation
- Maximum allowed path loss
- Impact of normal and extended cyclic prefix
- Impact of antenna configuration
- Range determination and site-to-site distance estimation
- Signal level and best server coverage plots
- SNIR and spectrum efficiency coverage plots
- Key measurements: RSSI, RSRP and RSRQ

- Site sharing options
- Improving coverage with the use of repeaters
- LTE downlink and uplink link budget exercises
- Planning tool configuration and simulations

Frequency Reuse and Interference Management (tool-based)

- Interference avoidance, cancellation and coordination
- Considerations for Single Frequency Network (SFN)
- Frequency-parallel schemes (OFDMA, SC-FDMA) in SFN
- Classical frequency reuse concept (integer reuse)
- Fractional frequency reuse (FFR) methods including soft reuse and partial reuse
- Comparison of FDD and TDD co-channel interference scenarios
- Role of X2 interface between eNBs in coordination of interference and load balancing
- Frequency planning performance evaluations and simulations

LTE Capacity Planning (tool-based)

- EPS bearers and QoS concept
- Traffic types and device types
- Capacity planning with MIMO
- Influence of Modulation and Coding Scheme distribution on sector capacity
- Overview of backhaul network options and requirements
- Exercises in capacity calculations

RAN Procedures Configuration

- Self-Organizing Network (SON)
- Synchronization signals distribution (PHY cell ID planning)
- Random access preamble allocation and dimensioning of PRACH opportunities
- Cell reselection and handover parameters
- Uplink and downlink transmit power control
- Feedback reporting configuration (CQI, PMI, RI)

LTE Inter-working with 2G, 3G

- Roaming
- Inter-working with 3GPP and non-3GPP networks

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COURSE OUTLINE

LTE and SON Introduction

- Features of LTE Releases and main radio parameters
- LTE / LTE-Advanced network architecture (UE, eNB, HeNB, RN, MME, S-GW, P-GW, HSS, etc.)
- SON concept
- SON history and features evolution over 3GPP Rel. 8, 9 and 10
- SON architecture types (centralized, distributed and hybrid)
- Heterogeneous Networks (HetNets) in the context of SON

SON Frameworks in NGMN, 3GPP and Research Projects

- NGMN SON use cases – self-planning/configuration, self-deployment and fault management
- 3GPP SON use cases – self-configuration, self-optimization and self-healing
- 3GPP Management Reference Model (NM, DM, EM)
- SON versus RRM (large and small scale resource management)
- SON research projects (e.g. SOCRATES)

LTE Self-Configuration (Plug & Play)

- Auto-connectivity (including X2 and S1 setup)
- Automated configuration of Physical Cell Identity (PCI) – confusion and collision free
- Automatic Neighbor Relation function (ANR)
- Self-configuration for HetNets (ANR, auto-connectivity)
- Relay Node auto-connectivity

LTE Self-Optimization

- Coverage and Capacity Optimization (CCO)
- Mobility Load Balancing (MLB)
- Mobility Robustness Optimization (MRO)
- RACH optimization
- Energy saving management
- Inter-cell interference coordination (ICIC)
- Minimization of Drive Tests (MTD)
- Coordination of SON functions

- 3GPP support for self-optimization (X2 interface, procedures and messages, UE reports for self-optimization)
- Self-optimization for HetNets (interference management, macro-network traffic offload, range expansion, etc.)

LTE Self-Healing

- Automatic network failure detection, diagnostics and recovering
- Cell degradation detection and improvement
- Cell outage compensation / mitigation

SON in Evolved Packet Core

- ANR and S1-flex (MME Pools) in the context of EPC optimization
- Signaling and latency optimization
- Voice network monitoring and resource optimization

3GPP Multi-RAT SON

- Self-planning issues for 2G (GSM) / 3G (UMTS) / LTE
- SON 2G - frequency planning, SON 3G – scrambling codes planning, SON LTE – PCI planning
- Cross-technology self-planning (spectrum management, antenna settings optimization, neighbor list management)
- Future of SON – Cognitive Radio Networks (SON to CRN evolution)

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